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Application number GB 0818362.6

1.	Your reference	**P43568-/NHE**	
2.	Full name, address and postcode of the applicant or of each applicant	**Pursuit Dynamics plc** **Shackleton House** **Kingfisher Way** **Hinchingbrooke Business Park** **Huntingdon PE29 6HB** **Cambridgeshire** **United Kingdom**	08333072003
	Patents ADP number *(if you know it)*		
3.	Title of the invention	**An Improved Process and System for Breaking an Emulsion**	
4.	Name of your agent *(if you have one)*	**Murgitroyd & Company**	
	"Address for service" to which all correspondence should be sent. This may be in the European Economic area or Channel Islands (see warning note below) *(including the postcode)*	**Murgitroyd & Company** **Scotland House** **165-169 Scotland Street** **Glasgow G5 8PL** **United Kingdom**	
	Patents ADP number *(if you know it)*	**1198015**	
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Description: **14**

Claim*(s)*: **n/a**

Abstract: **n/a**

Drawing*(s)*: **2**

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Statement of inventorship and right to grant of a patent (Patents Form 7): **0**

Request for search (Patents Form 9A): **0**

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11. I/We request the grant of a patent on the basis of this application.

Signature: **Subject: GB, Murgitroyd & Company, N. Hendry 80; Issuer: , European Patent Office, European Patent Office CA**

Date: **08 Oct 2008**

12. Name, e-mail address, telephone, fax and/or mobile number, if any, of a contact point for the applicant

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AN IMPROVED PROCESS AND SYSTEM FOR BREAKING AN EMULSION

The present invention is concerned with the processing of fluids. More specifically, the present invention provides a process and system for breaking emulsions comprising water and at least one other liquid.

An emulsion consists of two or more liquids, in which droplets of one liquid are dispersed throughout another liquid. The term “aqueous emulsion” is used hereinafter to describe an emulsion in which one of those liquids is water. The water may be either the dispersed phase or the continuous phase. Aqueous emulsions of this type are commonly encountered in the oil industry, where various techniques employed to retrieve the oil from below ground can result in the creation of a water-in-oil or oil-in-water emulsion. An example of one such retrieval technique is steam-assisted gravity drainage, where oil trapped in sands is liquefied by having steam pumped through the sands. Although this technique allows the trapped oil to be removed from the sands, the resultant slurry arrives at the surface as a water and oil emulsion. In order to separate the oil off from the water, it is necessary to break the emulsion by disrupting the chemical bonds which exist between the two liquids and thus encouraging coalescence of the dispersed liquid droplets with one another.

Conventional methods of breaking emulsions of this type very often rely on chemical demulsifying agents such as, for example, surfactants being added to the emulsion. For the agent to successfully break the chemical bonds between the liquids it is added to the emulsion and the emulsion is heated to an elevated temperature in a separation vessel, whereupon the desired reaction between the agent and the chemical bonds can take place. Utilising large quantities of such agents can have significant impact

on cost and environmental impact of the emulsion breaking process. Furthermore, heating the emulsion to a suitably high temperature and maintaining that temperature for many hours while the agents work to break the emulsion consumes a large amount of energy, which also adds to the cost and potential environmental impact of the process. Finally, filling, heating and draining a stand-alone separation vessel adds significantly to the time required to carry out the process.

It is an aim of the present invention to obviate or mitigate one or more of the aforementioned disadvantages.

According to a first aspect of the present invention, there is provided a process for breaking an emulsion of water and at least one other liquid, the process comprising:

(i) passing the emulsion through a passage of a fluid processing apparatus;

(ii) atomising the emulsion to form a vapour-droplet regime and turbulent mixing zone by injecting a transport fluid into the emulsion from a nozzle which opens into the passage;

(iii) vaporising water droplets in the vapour-droplet regime by passing the vapour-droplet regime through a low pressure region formed downstream of the nozzle by the injection of the transport fluid; and

(iv) condensing the vapour in the vapour-droplet regime.

The transport fluid may be compressible. The compressible transport fluid may be a gas. The gas may be steam or, alternatively, carbon dioxide.

The condensing step may be initiated by the condensing of the transport fluid downstream of the low pressure region.

The process may further comprise a final step of separating the water and the at least one other liquid in a separation vessel downstream of the fluid processing apparatus. The separating step may comprise a gravitational separation process in the separation vessel. Alternatively, the separating step may comprise a centrifugal separation process in the separation vessel.

The process may comprise repeating steps (i)-(iv) at least once.

The process may further comprise the step of adding a demulsifying agent to the emulsion. The agent may be added prior to step (i). Alternatively, the agent may be added during step (i).

The at least one other liquid may be an oil, wherein the emulsion is either a water-in-oil or oil-in-water emulsion.

According to a second aspect of the present invention, there is provided a system for breaking an emulsion, comprising:

at least one fluid processing apparatus comprising a passage having an inlet and an outlet, wherein the inlet is adapted to be connected to a source of the emulsion; and a transport fluid nozzle opening into the passage intermediate the inlet and the outlet, wherein the nozzle is adapted to be connected to a source of transport fluid; and

a separation vessel in fluid communication with the outlet.

The transport fluid nozzle has a nozzle inlet, a nozzle throat and a nozzle outlet, wherein the nozzle throat has a smaller cross sectional area than either the nozzle inlet or the nozzle outlet. The nozzle inlet may be adapted to be connected to a source of compressible transport fluid.

The transport fluid nozzle may circumscribe the passage.

The passage of the fluid processing apparatus may be of substantially constant cross sectional area from the passage inlet to the passage outlet.

The fluid processing apparatus may further comprise an additive port in fluid communication with the passage. The additive port may be in fluid communication with the passage immediately downstream of the nozzle.

The system may comprise a plurality of the fluid processing apparatus connected in series. Alternatively, the plurality of fluid processing apparatus may be connected in series and/or parallel to form an array.

The separation vessel may include a centrifuge.

The system may further comprise a holding tank adapted to supply emulsion to the inlet of the fluid processing apparatus.

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross sectional view of a fluid processing apparatus; and

Figure 2 is a schematic view of a system for breaking an aqueous emulsion.

Figure 1 is a vertical cross section through a fluid processing apparatus, generally designated 10. The processing apparatus 10 comprises a housing 12 within which is defined a longitudinally extending passage 14.

The passage has an inlet 16 and an outlet 18 and is of substantially constant circular cross section. In other words, the cross sectional area of the passage 12 is substantially constant from the inlet 16 to the outlet 18.

A protrusion 20 extends axially into the housing 12 from the inlet 16 and defines exteriorly thereof a plenum 22 for the introduction of a compressible transport fluid. The plenum 22 is provided with an inlet 24 which is connectable to a source of transport fluid (not shown in Figure 1). The protrusion 20 defines internally thereof the inlet 16 and an upstream portion of the passage 14. The protrusion 20 has a distal end 26 remote from the inlet 16. The distal end 26 of the protrusion 20 has a thickness which increases and then reduces again so as to define an inwardly tapering surface 28. The housing 12 has a wall 30, which at a location adjacent that of the tapering surface 28 of the protrusion 20 is increasing in thickness. This increase in thickness provides a portion of the wall 30 with a surface 32 which has an inward taper corresponding to that of the tapering surface 28 of the protrusion 20. Between them the tapering surface 28 of the protrusion 20 and the tapering surface 32 of the wall 30 define an annular nozzle 34. The nozzle 34 has a nozzle inlet 36 in flow communication with the plenum 22, a nozzle outlet 40 opening into the passage 14, and a nozzle throat 38 intermediate the nozzle inlet 36 and the nozzle outlet 40. The nozzle throat 38 has a cross sectional area which is less than that of either the nozzle inlet 36 or the nozzle outlet 40. The passage 14 also includes a mixing region 17, which is located in the passage immediately downstream of the nozzle outlet 40.

Figure 2 shows schematically a system for breaking an emulsion, generally designated 50, which includes a fluid processing apparatus 10 of the type shown in Figure 1. The system 50 comprises a holding tank 52 which receives an aqueous emulsion (e.g. oil and water) from a remote

location via a supply line 51. The holding tank 52 has an outlet 54 controlled by an outlet valve 56.

Downstream of the holding tank 52 is the fluid processing apparatus 10. The outlet 54 of the holding tank 52 is fluidly connected to the inlet 16 of the passage 14 shown in Figure 1 via a first processing line 58. Also shown in Figure 2 is a transport fluid supply 60, which is connected to the plenum inlet 24 of the processing apparatus 10 via a transport fluid supply line 62. A supply valve 63 controls flow of the transport fluid from the supply 60. Downstream of the processing apparatus 10 is a separation vessel 66, which is fed via a second processing line 64 fluidly connected to the outlet 18 of the processing apparatus 10. The separation vessel 66 has a drain line 68 which is controlled by a drain valve 70.

If necessary, a pump (not shown) may be provided on the first processing line 58 to pump the emulsion from the holding tank 52 to the fluid processing apparatus 10. The various valves 56,63,70 in the system, as well as the pump if present, may be controlled by a programmable system controller (not shown).

The process carried out by the system 50 will now be described, with reference to both Figure 1 and Figure 2. Whilst the system 50 is intended for use in breaking any aqueous emulsion, a preferred application of the system 50 will be described here in which the system is processing and breaking an oil and water emulsion. These oil and water emulsions are often the result in retrieval processes used in the oil industry for retrieving hard-to-extract oil deposits, such as where oil trapped in sand is retrieved by a steam-assisted gravity drainage process, for example.

Initially, the oil and water emulsion will be pumped to the surface from a well and then directed into the holding tank 52 via supply line 51. The emulsion can then be held in the tank 52 until processing is required. Where the emulsion is particularly viscous, a lighter oil or more water may be added at this stage to aid handling of the emulsion through the system. When it is time to process the emulsion, the system controller (not shown) can open the outlet valve 56 in order to allow the emulsion to flow along the first processing line 58 into the processing apparatus 10. At the same time as the outlet valve 56 is being opened, the control system also opens the supply valve 63 controlling the supply of transport fluid to the processing apparatus 10. Consequently, transport fluid flows from the transport fluid supply 60 into the processing apparatus 10 via the plenum 22. In this preferred embodiment, the transport fluid is a compressible gas which is heated in the transport fluid supply 60. The gas is preferably steam and the transport fluid supply 60 is preferably a steam generator.

Referring to Figure 1, the narrow throat 38 of the nozzle 34 accelerates the transport fluid so that a high velocity jet of transport fluid is injected from the nozzle outlet 40 into the fluid passage 14. At the same time, the emulsion is flowing through the inlet 16 of the passage 14. As the transport fluid is injected into the passage 14 from the nozzle 34 it imparts a shearing force on the emulsion as it passes the nozzle outlet 40. This shearing force atomises the emulsion, forming a flow made up of vapour and dispersed droplets which will hereinafter be referred to as a vapour-droplet flow regime. The injection of the transport fluid also creates an area of low pressure in the mixing region 17 of the passage 14 through which the vapour-droplet regime passes. In addition, as the transport fluid flows from the reduced cross sectional area of the nozzle 34 into the comparatively large cross sectional area of the mixing region 17 it will expand as well as accelerate. This expansion and acceleration of the

transport fluid creates a turbulent region within the mixing region 17, as the rapid change in the pressure and velocity of the transport fluid generates numerous unsteady vortices and a swirling of the transport fluid. The turbulent region 17 applies acceleration and deceleration forces on the droplets in the vapour-droplet regime, leading to a further atomisation of the droplets.

As the vapour-droplet regime flows towards the outlet 18 of the passage 14 it will begin to decelerate. This deceleration will result in an increase in pressure within the passage 14. At a certain point within the passage 14, the decrease in velocity and rise in pressure will result in a rapid condensation of the vapour in the vapour-droplet regime. The point in the passage 14 at which this rapid condensation begins defines a condensation shockwave within the passage 14. A rise in pressure and consequent phase change takes place across the condensation shockwave, with the flow returning to the liquid phase on the downstream side of the shockwave. The position of the shockwave within the passage 14 is determined by the supply parameters (e.g. pressure, density, velocity) of the transport fluid, the geometry of the fluid processing apparatus, and the rate of heat and mass transfer between the transport fluid and the emulsion.

The injection of the transport fluid has a number of effects on the emulsion. Firstly, the emulsion is heated by the heat transfer which takes place between the transport fluid and the emulsion. This heating reduces the viscosity of the emulsion and helps weaken the chemical bonds between the liquid components of the emulsion. This also weakens the interfacial film between the two liquids, thereby reducing surface tension. The chemical bonds and interfacial film are broken down by the physical disruption of the emulsion caused by the shear forces and turbulence

generated by the transport fluid. The breaking of the chemical bonds and disruption of the interfacial film in this way encourages the droplets of the various liquids in the emulsion to coalesce with like droplets. In the vapour-droplet regime, droplets of water from the emulsion can coalesce with other water droplets or the condensing steam. Furthermore, the increased temperature and low pressure area caused by the injection of the transport fluid into the mixing region 17 vaporises the atomised water droplets into the vapour-droplet regime. A resultant cavitation process takes place within the mixing region 17 due to the vaporisation and subsequent rapid condensation of the water droplets in the emulsion.

The aforementioned mechanisms taking place in the fluid processing apparatus break the chemical bonds and the interfacial film between droplets of the liquids, thereby reducing the surface tension and encouraging the droplets of each liquid to separately coalesce together. Thus, as the emulsion leaves the outlet 18 of the fluid processing apparatus 10, the droplets in the dispersed phase are coalescing together such that the emulsion has broken and is separating into its constituent parts.

The liquids leaving the outlet 18 of the fluid processing apparatus 10 are carried via the second processing line 64 to the separation vessel 66. The constituents of the emulsion can be left to complete their separation under gravity. The constituent liquid having the greatest density will fall to the bottom of the vessel 66. It can then being removed from the vessel 66 via the drain line 68 when the drain valve 70 is opened. The other liquids can then be removed in turn thereafter via the same drain line 68.

By atomising the aqueous emulsion to form a vapour-droplet flow regime in the manner described above, the process and system of the present

invention physically disrupt the chemical bonds and interfacial film between the dispersed and continuous phases which normally prevents the droplets of the dispersed phase liquid from coalescing with one another. The heat transfer caused by the injection of the transport fluid also assists with this disruption, as the heating of the emulsion reduces its viscosity and weakens the interfacial films of the dispersed phase liquid. The vapour-droplet flow regime created by the atomisation of the emulsion encourages coalescence of individual water droplets to one another and the steam, in instances where steam is being used as the transport fluid. The injection of the transport fluid into the emulsion raises the temperature of the emulsion whilst creating a low pressure region. This ensures the vaporisation of the atomised water droplets at a lower temperature than if at atmospheric pressure.

It is believed that the process of the present invention may also disrupt the electrical charge which naturally causes each droplet to repel one another. This disruption is caused by one or more of the following effects: the cavitation caused by the vaporisation and subsequent rapid condensation of the water droplets immediately thereafter, a static charge build up due to the colliding droplets in the turbulent vapour-droplet phase, and the shear forces imparted by the transport fluid on the emulsion. Disrupting, and hence neutralising, the charge in this way allows the droplets to overcome their natural repulsion. It is also believed that the process of the present invention may change the pH of the emulsion, which can also assist with this neutralisation of the charge between droplets. This change in pH may be a result of the release and possible re-absorption of carbon dioxide from the water as it is vaporised, or may be a result of gas being released from solution when passing through the low pressure region. Where steam is being used as the transport fluid, it may also

result from carbon dioxide being trapped in the steam and carried from the steam generator.

Whilst the process and system of the present invention provide an effective arrangement for breaking emulsions it may be beneficial in certain circumstances to add a demulsifying agent to the emulsion to assist in the break up. One such example is where an emulsifier has been added to help create the emulsion in the first instance. In the present invention, the atomisation of the emulsion by the transport fluid to create a vapour-droplet regime exposes a large percentage of the surface area of the liquids to maximise the action of the demulsifying agent. Thus, the agent can be intimately mixed into the emulsion, thereby reducing the amount of agent required to break up the emulsion successfully. Therefore, even if the process and system of the present invention involve the use of a demulsifying agent they will be less expensive and less environmentally damaging than existing processes which use large quantities of such agents for breaking emulsions.

As the passage of the fluid processing apparatus is of substantially constant cross sectional area, the system has no restrictions in the flow path of the emulsion from the holding tank to the separation vessel. Thus, the system is able to handle emulsions which include solids, as these solids will not block the system once they are in the system. Solid deposits can occur in water and oil emulsions when small particles (e.g. sand or grit) agglomerate in the emulsion. The disruption caused by the shearing force and turbulence of the transport fluid in the processing apparatus will break up any such solid deposits present in the emulsion.

The system can be installed into an existing processing line. It therefore does not need to operate as a stand alone process. The heating which

occurs following the introduction of the steam or other transport fluid removes the requirement for dedicated heating means to be employed in the process. By varying the density of the transport fluid and/or the pressure at which it is introduced to the processing apparatus, the heat transfer between the transport fluid and emulsion can be controlled. The process and system of the present invention is therefore able to consume less energy than typical emulsion-breaking processes and systems which rely on inefficient stand-alone heated vessels. As the process of the present invention is continuous, it will also require less time to break the emulsion than such stand-alone arrangements.

Although a preferable feature of the system, the holding tank is not essential. Instead, the inlet of the fluid processing apparatus may be directly connected to the source of emulsion.

Where the addition of a demulsifying agent is required, the agent may be added prior to the emulsion reaching the fluid processing apparatus. For example, it may be added to the holding tank (where present) or else in the first processing line upstream of the fluid processing apparatus. Alternatively, the processing apparatus may include an additive port which opens into the passage. The additive port may be located between the inlet and the nozzle, or it may alternatively open into the mixing region immediately downstream of the nozzle. The agent can then be entrained into the emulsion as it passes through the fluid processing apparatus. In a further alternative, the agent may also be added once the emulsion has left the outlet of the fluid processing apparatus, in order to supplement the process of breaking the emulsion that has already gone on within the fluid processing apparatus.

Whilst the system preferably includes a separation vessel to complete the separation of the liquids once the emulsion has been broken, it is not essential for the process of breaking the emulsion itself. The separation vessel may be provided with a centrifuge which will complete the separation of the liquids due to the centrifugal force generated in the centrifuge. The separation vessel may also include a number of drain lines and drain valves for draining the separated liquids to separate locations.

Where required, the process can be repeated to ensure successful breaking of the emulsion. To facilitate this, the system may include a return loop and diverter valve which may selectively return the emulsion from the passage outlet back to the passage inlet instead of to the separation vessel or other downstream location. Alternatively, the repeating of the process steps may be achieved by adding an array of fluid processing apparatus to the system. The array of fluid processing apparatus may comprise a plurality of apparatus in series, in parallel, or a combination of the two.

The system may further comprise pressure regulating valves at the upstream and downstream ends of the system for controlling pressure and temperature in the system. These valves may be controlled by the system controller, where present.

The heating of the transport fluid is preferable, but not essential, to the process and system of the present invention. As stated in the foregoing description, the compressible transport fluid is preferably steam. However, alternative transport fluids may be used. One such alternative is carbon dioxide.

These and other modifications and improvements may be incorporated without departing from the scope of the present invention.

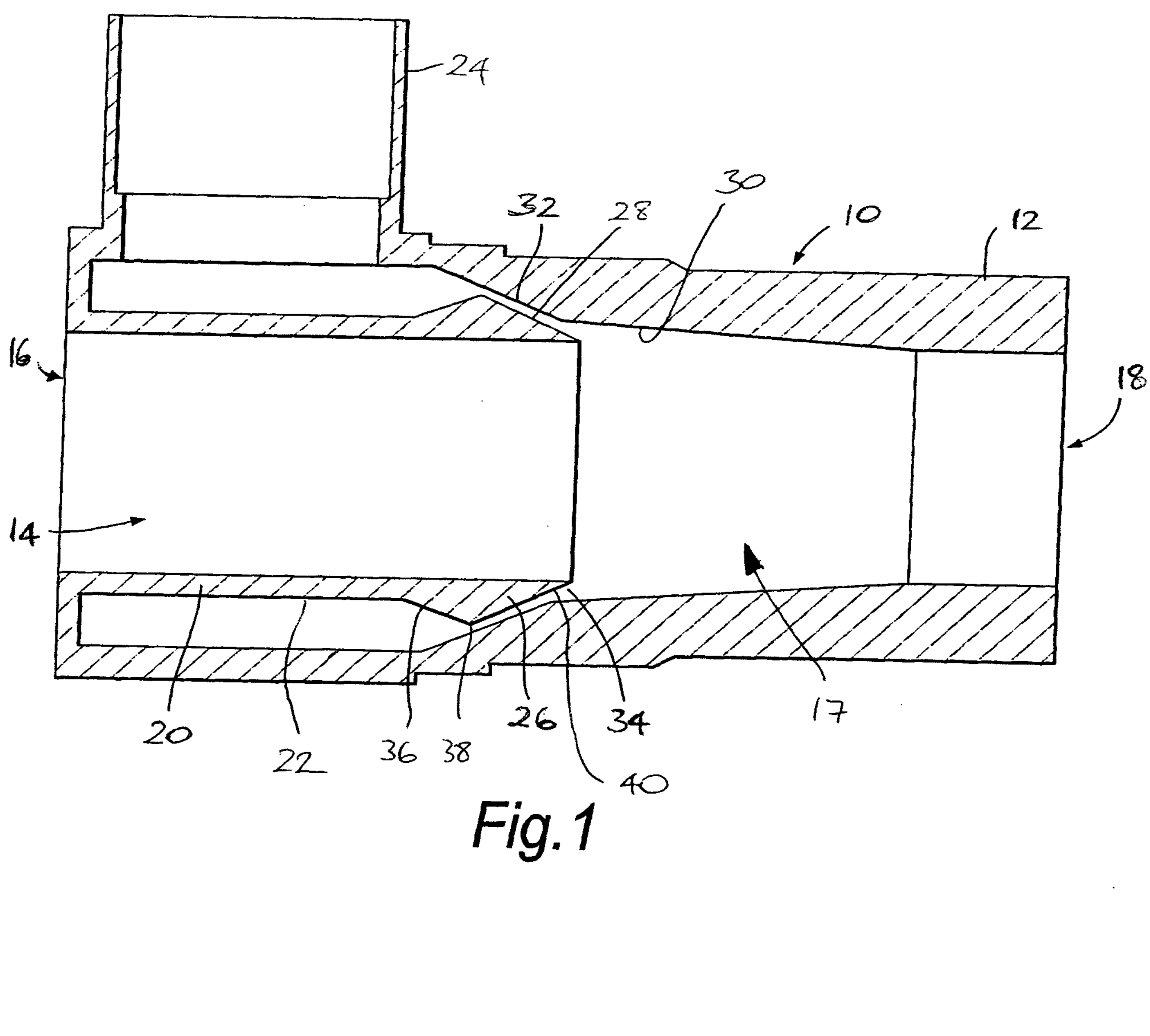

Fig.1

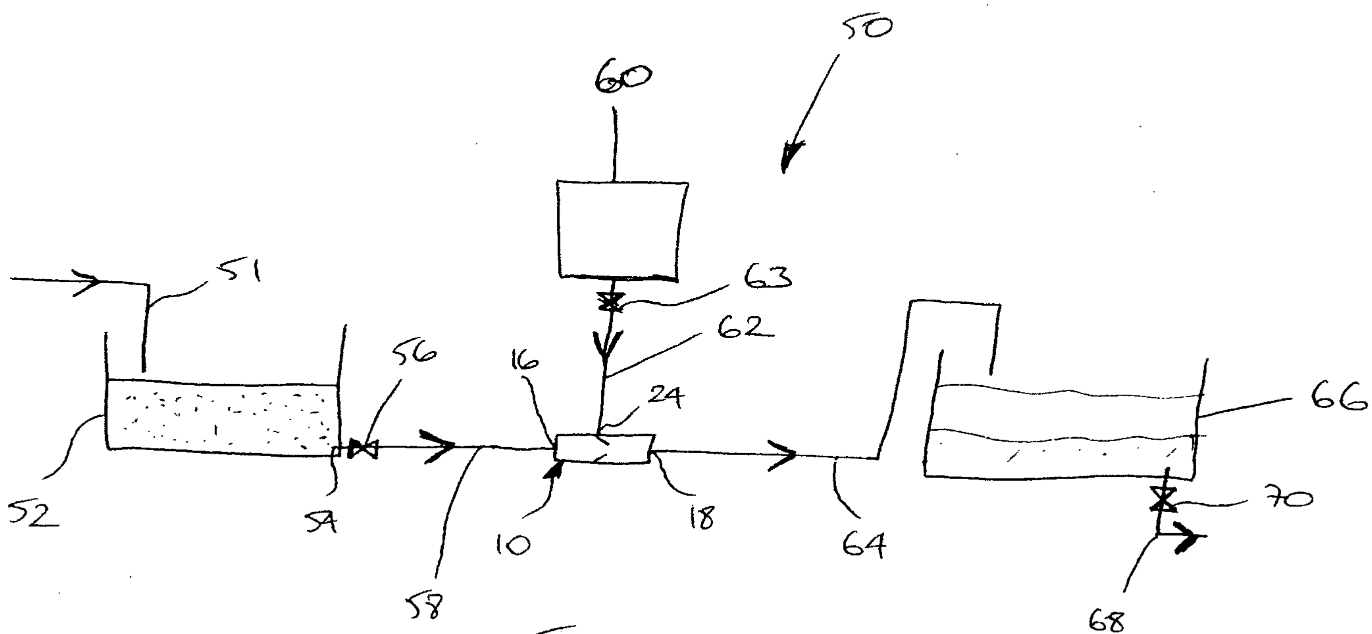

Figure 2